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IJAZAH: BACHELOR OF AGRICULTURE SCIENCE WITH HONOURS (HORTICULTURE AND LANDSCAPE)

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EFFECT OF COMMERCIAL MYCORRHIZA APPLICATION ON THE GROWTH PERFORMANCE OF CASTOR (*Ricinus communis* L.)

KELVIN KALIANON

DISSERTATION SUBMITTED IN PARTIAL FULLFILMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF AGRICULTURAL SCIENCE WITH HONOURS

HORTICULTURE AND LANDSCAPE PROGRAMME
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2014

DECLARATION

I hereby declare that this dissertation is based on my original work except for citation and quotation which have been duly acknowledged. I also declare that no part of this dissertation has been previously or concurrently submitted for a degree at this or any other university.

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ABSTRACT

This study was conducted from August 2013 to November 2013 outside the Greenhouse area of School of Sustainable Agriculture (SSA), Universiti Malaysia Sabah. This study was carried out to determine the effect of commercial mycorrhiza application on the growth performance of Castor (*Ricinus communis* L.) throughout 90 days of study. The treatments in this study were three different concentrations of commercial mycorrhiza MYCOGOLD, fertilizer treatment (NPK Green) and control treatment. Each treatment consisted of six replications. The three different level of commercial mycorrhiza were 50 g, 100 g and 150 g while the amount of fertilizer applied is 17.56 g. The experimental design used was Completely Randomized design (CRD) and all the collected data were analyzed by using one one-way ANOVA statistical test at 0.05% significant level. As the results, application of 50 g, 100g and 150 g MYCOGOLD slightly increased the vegetative growth of *Ricinus communis* L. Application of 17.56 g of NPK fertilizer was seen to increase the overall growth of *Ricinus communis* L. Results for evaluations of post-harvest parameters however showed that several replicates experienced nutrient deficiency. Yield of capsules were managed to be obtained at the end on day observation. Quantification for mycorrhizal infections on roots of Castor showed significant increase starting from week five until week nine. Nevertheless, the mycorrhiza was found to be inefficient in its performance due to the high phosphorus (P) content (167.408 ppm) in the compost soil used. Thus, it is very crucial to apply mycorrhiza inoculum in soil with low level of phosphorus content in order to get the fungi maximum performance.

ABSTRAK

***Mengkaji kesan penggunaan mikoriza terhadap pertumbuhan vegetatif Kastor Ricinus communis* L.**

Kajian ini telah dijalankan dari Ogos 2013 hingga November 2013 bertempat di sekitar kawasan Rumah Hijau Sekolah Pertanian Lestari (SPL) di Universiti Malaysia Sabah. Kajian ini dijalankan untuk mengkaji kesan konsentrasi berbeza mikoriza komersial kepada prestasi pertumbuhan Kastor (Ricinus communis L.) sepanjang sembilan puluh hari tempoh eksperimen. Rawatan dalam kajian ini terdiri daripada tiga kuantiti berbeza mikoriza komersial MYCOGOLD, rawatan baja (NPK Hijau) dan kawalan. Setiap rawatan terdiri daripada enam replikasi. Tiga kuantiti berbeza bagi mikoriza komersial adalah 50 g, 100 g dan 150 g manakala jumlah baja yang digunakan ialah 17.56 g. Reka bentuk uji kaji yang digunakan adalah reka bentuk Rawak Lengkap (CRD) dan semua data yang dikumpul telah dianalisis dengan menggunakan ujian statistik satu-hala ANOVA pada aras signifikan 0.05%. Merujuk kepada keputusan yang diperolehi, kuantiti MYCOGOLD sebanyak 50 g, 100 g dan 150 g dilihat mampu meningkatkan pertumbuhan vegetatif Ricinus communis L. manakala aplikasi baja NPK Hijau dengan jumlah 17.56 g dilihat dapat meningkatkan pertumbuhan keseluruhan tanaman Kastor. Keputusan yang diperolehi untuk penilaian pasca parameter tuaian bagi Ricinus communis L. bagaimanapun menunjukkan kebanyakan tumbuh-tumbuhan mengalami kekurangan nutrien. Hasil kapsul telah berjaya diperolehi pada akhir pada hari pemerhatian. Kuantifikasi untuk jangkitan mikoriza pada akar Kastor menunjukkan peningkatan signifikan mulai minggu lima sehingga minggu sembilan. Walau bagaimanapun, aplikasi mikoriza didapati tidak begitu berkesan dalam prestasinya kerana kandungan fosforus yang tinggi (167.408 ppm) di dalam tanah kompos yang digunakan. Oleh itu, adalah sangat penting untuk menggunakan tanah dengan kandungan fosforus yang rendah untuk mendapatkan prestasi maksimum mikoriza.

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LIST OF SYMBOLS, UNITS AND ABBREVIATIONS

ANOVA	Analysis of Variance
cm	Centimeter
Ha	Hectare
IPM	Integrated Pest Management
Kg	Kilogram
m	Meters
mm	Millimeter
MOP	Muriate of Potash
R	Radius
SSA	School of Sustainable Agriculture
SPSS	Statistical Package for Social Science
TSP	Triple super phosphate (fertilizer)
Π	Pie (with the value 3.1459)
%	Percentage

CHAPTER 1

INTRODUCTION

1.1 Introduction

Currently, the world is facing a massive shortage of continuous supply for non-renewable sources of fuel from which they typically obtained by drilling out of the earth's core. In relation to that, humans are now trying to get this much coveted oil through sustainable methods. This has indirectly leads to the vast cultivation of oil palm crops worldwide as we have seen nowadays. Our country Malaysia itself is actually the second largest producer for oil palm in the world after Indonesia. Other than oil palm, several more agricultural commodities like camelina, corn, jatropha, soybean and rapeseed were cultivated intensively across the globe. These crops are among major sources specifically for biofuel energy which are of high demand nowadays (Davies and Hossain, 2010). By opting to go with a more environmental-friendly system, we can now secure our production of renewable sources of biofuels. However, this alternative source for fossil fuels is seemingly started to create its own challenges that have something to do with the environment (Attanatho *et al.*, 2004). Issues such as excessive usage of chemical pesticides, soil infertility, disruption of the ecosystem and changes in biodiversity are occurring more often. Soon enough, statements claiming that the blame should be put on the enormous planting of oil palm crops become the headlines in any papers. Some even says that scientific research for other less troublesome oil-producing crops must immediately start. There are certain varieties of plant with oil-possessing properties were then successfully managed to be found by scientists. Among the crops is Castor bean (*Ricinus communis* L.). Castor is a non-edible oil seed crops used to produce biodiesel. Oilseed crops are important crops with very high commercial and economic value and are reported to have mycorrhizal association (Aher., Bhalerao., Khapake and Deshmukh 2011). Nowadays at the world scale, castor is still only a minor crop (Scholz and Nogueira da Silva, 2008). The production of Castor bean is concentrated in Brazil, China, India and Mozambique, which together account for more than 90% of castor world acreage and production. Castor or scientifically known as *Ricinus communis* L. is a very ancient oilseed crop.

The major reason on why castor is cultivated is due to the high oil content of its seeds which ranges between 42 and 58%. Castor contains a high proportion (84-90%) of ricinoleic acid (12-hydroxy-cis-9-octadecenoic acid), which is a monounsaturated hydroxy fatty acid. And because of that reason, castor oil is not suitable for edible purposes. Instead, the oil has been extensively used in local medicines mainly as a laxative and a lamp oil, and more recently utilized/used in manufacturing sector (Brigham 1993; Weiss 2000). Castor can be regarded as an underutilized oilseed crop. Castor also has a great potential in multiple industrial applications such as paints, varnishes, cosmetics, polymers, bio lubricants and biofuels, mainly due to its high-ricinoleic seed oil (Brigham 1993; Weiss 2000). The future prospects for an increasing demand of castor oil are largely based on its use in biodiesel production. However, due to the high viscosity of the methyl ester of ricinoleic acid that exceeds the maximum values for kinematic viscosity in biodiesel standards could hampers the use of castor oil for biodiesel production (Knothe 2008). Nevertheless, a new perspectives for large-scale use of castor oil as a biodiesel feedstock opens up upon the discovery of a castor mutant in which ricinoleic acid is partly replaced by oleic acid, which accounts for 78% of the total fatty acids (Rojas-Barros *et al.*, 2004).

Castor Bean (*Ricinus communis* L.) belongs to the Euphorbiaceae family which is also known as the spurge family. Euphorbiaceae family is consists of more than 280 genera and 8000 species of plants and trees worldwide. Despite the fact, Castor bean is a single-species genus. This type of plant sometimes may contain white latex, which could be irritable (Purseglove, 1981). The closest species to *Ricinus communis* L. comprised of Cnidoscolus Pohl. species (spurge nettle), Croton L. species, Crotonopsis Michx. species (rush-foil), Mercurialis L. species (mercury), Acalypha L. species (copperleaf), Tragia L. species, Stillingia L. species (Garden), Phyllantus L. species, Andrachne L. species, and Euphorbia L. species (spurge) (Fernald, 1950).

Castor bean is a short-lived perennial that lives mostly in the tropical areas, like in Malaysia and it is known to be a wind-pollinated plant. Range of the leaves is from 10 to 76 cm wide. The palmate is divided into 5 to 11 lobes, and can reach heights of 91 to 366 cm. Shape of a Castor bean leaf is spirally arranged, deciduous and united with stipules ranged from 1 to 3 cm long. Range of petiole is from pale green to red, round, with length of 8 to 50 cm (Auld *et al.*, 2003). There are two nectiferous glands located at the lamina junction. Two glands are located on both sides at the base with one or more glands can be found on the upper surface toward the base. Color of the leaves vary from green, purple to red and some can be used as ornamentals plants in home gardens. The stems have well-marked nodes, are green or red in color and becoming hollow with age. At the sixth to tenth node in dwarf and early maturing cultivars, a single stem would terminates into an inflorescence (Brigham, 1970). In later maturing cultivars, termination of stems may occurs at the 8^{th} to 16^{th} node while in tall and wild type plants, the process take place at the 40^{th} or more node. As the panicle develops, two to three sympodial branches grow out from each node. Development of inflorescence begins from these branches. Colors of the flowers are green to yellow without petals borne in a terminal, and with many flowered panicles ranging from 10 to 40 cm long. Male flowers are located at the base with female flowers on the 30-50% of the upper inflorescence, and both are unisexual (Purseglove, 1981). The plant is monoecious, with the pistil found on the upper raceme with stamens below it, thus resulting in frequent cross-pollination (Martin and Leonard, 1967). On the same inflorescence, most of the female flowers start setting seeds and fruits prior to the opening of the male flowers, hence making the plants protogynous. When it is dry or being touched, the anther will burst scattering the pollen out and soon after the pollen shed, the male flowers abscises. Glands on young leaves below the inflorescence will exude nectar which will attracts insects as the flowers start to open (Purseglove, 1981). The fruit is smooth, spiny and either dehiscent or indehiscent. It contains three to four celled capsules with each cell containing a mottled-seed. Shape of the seed is obovoid with a prominent hilum or caruncle (Martin and Leonard, 1967). The Latin word for tick is *Ricinus* and the seeds resemble an Arachnid in morphology (Tyler *et al.*, 1976).

Mycorhizza is a common term used in defining the symbiotic relationship between a plant and a mycorhizzal fungus. This symbiotic relationship actually happens as the fungi started to spread its hyphae through the soil and infects the roots of plants creating specialized structures for the exchange of nutrients. This association generally benefits both organisms in terms of continuous carbon supply to the fungi and increased nutrient uptake (primarily phosphorus) for the plant (Severino *et al.*, 2012). Typically, each plant and mycorhizza fungi is involved in multiple simultaneous relationships. The range of all plant species involved in mycorhizzal associations is estimated to be around 70-90%. Notably, *Brassicaceae* and *Proteaceae* are the two large and diverse families of plants which are non-mycorrhizal. Indeed, mycorrhizal association is crucial in enhancing the development of a plant. Some mycorrhizal associations may be obligatory, while others are facultative and in certain conditions the fungus can even have a parasitic relationship with the plant. The importance of this relationship for plant health varies much depending on the species of the plant and fungus involved (St. John, 2000).

These relationships are complex and need in-depth research to be well understood. It is believed that mycorrhiza play an important role in maintaining plant community structure by conferring a greater benefit to some plant species than to others. Scientists have discovered many types of mycorrhiza which lead to six groups of classification. The most two prominent groups are the ectomycorrhiza and the endomycorrhiza (Castellano and Molina, 1989). The former coats the outer part of roots and infect the cell wall of root tissue. This kind of mycorrhizae produces fruiting bodies and associate with woody plants. Most of the known edible forest mushrooms are ectomycorrhizal fungi (Ohmasa and Yamada, 2001). Ectomycorrhiza is actually a very large diverse group of fungi that associates only with a minority of the plant species. On the other hand, endomycorrhiza is a type of fungi which penetrates into root cells and form tree-like structures called arbuscules. Arbuscules are thought to assist in nutrient exchange. Arbuscules are also known as arbuscular mycorrhizal fungi, or AM fungi. These are a completely different phyla or division of fungi which do not produce mushrooms and have tiny underground fruiting bodies that are rarely seen by people. Compared to the ectomycorrhiza, endomycorrhizal fungi are far less diverse comprised of only six genera. However, they do make association with the vast majority of plants, both herbaceous and woody. Basically, source of mycorrhiza are obtained through isolation from plants that associate with these fungi. Nowadays, mycorrhiza are commercially available in the market and widely used in nursery production. It is becoming an increasingly common practice to apply inoculants of mycorrhiza in the nursery industry. Purposes of adding mycorrhiza are to lower the mortality rates and reduce the consumption of water and fertilizer despite concerning much whether the nurseries are producing native, ornamental or agricultural plants. Doubts arise much on the uncertainty concerning where to obtain the fungi, what types to use, the quality of commercially available products and the most effective application methods. Different kinds of mycorrhizal inoculants sold in the market may contain varying amounts of different species of fungi, different percentages of viable pores, as well as additives such as fertilizers, and hydrogels (Ortega *et al.*, 2004). Some inoculants contain spores specific to particular species, while others contain a broad mixture. Determination of a special plant's needs and the present soil conditions is the first step in choosing a commercially produced inoculant.

Currently, there are many companies that sell mycorrhizal inoculants. Generally speaking, the best way to learn about the products is to contact the suppliers directly. Purchasing commercially produced mycorrhizal inoculants could be more expensive but it is much less-labor intensive than collecting forest soil (Rillig, 2004). Commercial products may have higher concentration of spores and are more uniform. Apparently, there are no doubts regarding to the fact that mycorrhiza brings many benefits in facilitating healthy plant growth. Mycorrhiza increases the surface area of a plant's root system, resulting in the enhancement of the plant's capability to absorb more water. Due to the increment of water uptake, the rate of survival for transplants will also be increased. Besides that, the plant's resistance towards drought may also be enhanced. In particular cases, mycorrhiza increase a plant's access to nutrients such as zinc and phosphorus, which can be crucial in tropical soils where phosphorus availability is low. For nodule-forming plants, mycorrhiza benefit them by increasing the process of nitrogen fixation. Plants that associate with mycorrhiza will receive proper nutrition and are more able to resist disease. This is actually one way that mycorrhiza help plants resist soil borne diseases (University of Washington, 2006).

1.2 Justification

Environmental pollution and diminishing supply of fossil fuels are the key factors leading to search for the alternative sources of energy. Currently, 86% of the world energy consumption and nearly 100% of the energy needed in the transportation sector is met by the fossil fuels (Dorian et al., 2006). Since the world's accessible oil reservoirs are gradually depleting, it is important to develop suitable long-term strategies based on utilization of renewable fuel that would gradually substitute the declining fossil fuel production. Recently, environmentalists have started to debate on the negative impact of biodiesel production from edible oil (Butler, 2006). They believed that large-scale production of biodiesel from edible oils may bring global imbalance to the food supply and demand market. These people also claimed that the expansion of oil crop plantations for biodiesel production on a large scale may increase deforestation in countries like Indonesia, Brazil and also in our country Malaysia. Thus, in order to overcome this devastating phenomenon, suggestions and research have been made to produce biodiesel by using alternative or greener oil resources such as the non-edible oils. Castor bean (*Ricinus communis L.*) is a non-edible oil seed crop and has been widely accepted as an agricultural solution for all subtropical and tropical solutions which require the need for commercial crops with low impute costs and at the same time provides traditional farming with a viable income from current non-productive lands. And at the same time, supplies of castor seeds for the production of biodiesel can also be continuously provided. It is truly a holistic bioenergy project in either both developing or developed tropical and sub-tropical countries all around the world to gain the benefits of cultivating Castor bean.

1.3 Research objective

The main objective of this study is to investigate the effect of commercial mycorrhiza application on the growth performance of Castor bean (*Ricinus communis L.*).

1.4 Hypothesis

H_0: There is no significant difference in the effect of commercial mycorrhizae inoculants application on the growth performance of Castor (*Ricinus communis L.*).

H_a: There is a significant difference in the effect of commercial mycorrhizae inoculants application on the growth performance of Castor (*Ricinus communis L.*).

CHAPTER 2

LITERATURE REVIEW

2.1 Castor Oil Plant (*Ricinus communis* L.)

Forero, C.L.B (2005) states that Castor oil plant, or commonly known by scientific name Ricinus communis is a species that belongs to the Euphorbiaceae family. The plant is also called as Palma Christi. The origin of Castor plant is from Africa, but it is also found in both cultivated and wild states in all tropical and subtropical countries of the world. Nielsen *et al.* (2011) states that Castor plant started to spread to the Mediterranean, the Middle East and India about a thousand years ago. This plant is able to stand long periods of drought and is well-adapted to both arid and wild conditions. Nielsen also claims that there are three cycles of flowering undergone by Castor plant, namely precocious, median and delayed. In precocious cycle, flowering will occurs 45 days after sowing. Whereas in the median cycle, flowering presents at an intermediate time between the precocious and delayed cycle and usually the duration of flowering is between 90 to 120 days after sowing.

2.2 Description of Castor Oil Plant, its distribution and ecology

According to Ogunniyi (2006) and Ramos *et al.* (1984), the main reason on why castor is cultivated is actually to get its seeds which yield viscous, pale yellow non-volatile and non-drying oil, in which the oil has been used only for medicinal and industrial purposes. Stubiger *et al.* (2003) and Duke (1983) state that Castor oil is widely used as a human laxative-cathartic agent, especially in cases of certain radiological examinations which require prompt and thorough evacuation of the small intestine. Jan de Jongh *et al.* (2011) state that there was no comprehensive classification has been undertaken even though castor plants show a lot variation in both morphology and agronomic characteristics. Castor reproduces through both self and cross pollination methods. All varieties of castor can self-pollinate to reproduce. Wind pollination between separate strands will be prevented with an isolation distance of 300-700 m. castor has several branches with each are terminated by a spike that is up to 30 cm long. After it reaches maturity, each spike would carry 15 to 80 greenish to purple capsules with a smooth or prickly surface. Each capsule contains three seeds that can be oblong or round with color ranged from black to white mottled. Its Latin name *ricinus* was inspired by the plant's resemblance toward blood filled ticks, as *ricinus* means tick in Latin language. It got the name "castor oil" from one of its function which is as a replacement for *castoreum*, a perfume base made from the dried perineal glands of beaver.

Wild varieties of castor will produce seeds that do not ripen simultaneously. Prior reaching maturity, the seeds are shed when the fruits open spontaneously, leading to considerable seed losses. Hence, redundant harvesting of the same crop is required. Seeds of wild varieties' castor are smaller and have smaller kernels with more shell and lesser oil content. Fewer tendencies to seed shedding and shorter time span in reaching maturity are among the characteristics shown in improved varieties of castor. In addition, the overall size of seeds for these varieties are larger and smaller, hence contribute to easier harvesting process. Examples of wild castor varieties are *Baker 22*, *Baker 44*, *McNair 1*, *Hale*, *Hazera*, *HD912*, *IAC 2008*, *Kansas*, *Lynn*, *Negus*, *Pronto*, *Rica*, *SKI-7*, *S-56*, *T-3*, *UC-53*, *Venda* and *GCH-series* hybrids. Nowadays, some of the older varieties such as *Hale* and *Lynn* are used to produce hybrid seeds.

2.1.2 Potential of Castor Oil Plant for biofuel production

Nielsen *et al.* (2011) states that Castor is currently considered experimental as a biofuel feedstock and mainly a crop of interest for small scale farmers in areas with challenging agro-climate conditions. This is due to statement which claims that other energy crops are likely to be more profitable under mechanized high-input farming. Nielsen also states that because of its high price on the world market compared to other vegetable oils, Castor oil is not an attractive raw material for biofuel production. One of the rationale ways to change this situation is by increasing the tax incentives, just like what happened in Brazil. In dry and isolated areas where biofuel is produced and consumed locally, the available options for oil crops may be limited and hence will leads to high competition due to the low transport costs involved compared to just importing the oil from other country. Small farmers in the North-East of Brazil that are involved in cultivating Castor as a biofuel crop are fully supported by the government. In India and other countries, Castor is being inter-cropped mainly as a biofuel crop with other types of crops such as Jatropha (Sharma and Sarin, 2007). Mixing Castor with Jatropha can reduce the production risks. During the upstart phase, Castor can give full yields in the first year, whereas for Jatropha, its yields will reach their maximum production after five to eight years (Rao *et al.*, 2008). The overall profitability of Castor compared to non-toxic oil crops is reduced due to the low value of seed cake caused by the plant's own toxicity. Press cake made from non-toxic oil crops can be sold as a high-protein fodder supplement. And since the oil contains very few plants nutrients, it can be returned to the field as organic manure. This practice is believed can helps to prevent overuse of the soil which can leads to exhausting (Pramanik, 2003).

2.1.3 Background and general properties of Castor oil

Forero (2005) claimed that Castor oil can be obtained from the seeds of Palma Christi through extraction process. According to Akpan *et al.* (2006), Castor oil is one of the few naturally occurring glycerides with high purity because of the fatty acid portion which is nearly 90% of ricinoleic. The seeds contained of approximately 46% oil content. Viscosity of Castor is high and its coloration ranges from a pale yellow to colorless. Its taste is highly unpleasant and has a soft and faint odor. Castor oil dissolves easily in ether, alcohol, chloroform, glacial acetic acid, carbon sulfide and benzene. It is made up of triglycerides components which comprised of 91-95% ricinoleic acid, 4-5% linoleic acid and 1-2% stearic and palmitic acid. On the other hand, Salimon *et al.* (2010) states that Castor oil is rich in a very unique hydroxyl fatty acid which is the ricinoleic acid ($C_{18}H_{34}O_3$), structurally as *cis*-12-hydroxyoctadcca-9-enoic acid and hydroxylated with 18-carbon fatty acid having one double bond. Salimon also claimed that the characteristics of Castor oil from other countries like Brazil, Nigeria, India, China and Africa had been studied. However in Malaysia, there were only a few researches that had been carried out on Castor oil. Due to its various properties, Castor oil is widely used in the industrial field besides being commonly used only as a laxative. Castor oil is used in the textile and manufacturing of waterproof industries for moisturizing and removal of grease in fabrics. Whereas in the steel industry, it is used in cutting oils and lubricants for steel lamination at high temperatures and it is also used in other liquids that are necessary for steel work. Castor oil is used for the production of high performance motor oil and braking fluids in the automotive industry. Apart from that, it is also utilized as a softener in the tanning industry and in the production of fluids for hydraulic devices, artificial leather, varnish, paint, linoleum and insulator. Additionally, Castor oil can be used as a raw material for the fabrication of plastics (Baldwin and Cossar, 2009).

2.1.4 Centre of Origin and Current Distribution of Castor Oil Plant

Jan de Jongh *et al.* (2011) claimed that Castor plant was originated from the North-East Africa before it spread to the Mediterranean, the Middle East and India. Nowadays, Castor is cultivated and growing in the wild throughout the drier tropical, warm temperate and subtropical regions in the world, between 40° South to 52° North. Castor plant can be found at altitudes from the sea level to about 3000 m in areas where there is no or only slight frost.

2.1.5 Climate and Soil Requirements for Castor Oil Plant

According to Arrakis *et al.* (2011), Castor is a C3 pathway plant. The optimal growth for this plant is at constantly high temperatures of 20-26^{0}C but it also can tolerate temperatures between 0 and 40^{0}C. In colder areas for example in southern Spain, Castor will only grow well if the summers are sufficiently warm. Castor would fail to set seeds if the temperature is too low or too high. It is a pioneer plant that is found growing in abandoned farmland, flood zones and along the roadways. Castor can be soon succeeded by grass and trees if no disturbance occurs. Arrakis also states that the approximate amount of rainfall needed by Castor between the planting and harvesting period is 500 mm. However, it still can grow in areas with medium amount of rainfall. Number of days required for one growing season of castor is 140-180 days, depending on the variety. No seeds will be set under severe water stress condition. High rate of humidity would increases pest and mold problems. The ideal range of humidity is assumed to be between 30-60%. 300-1800 m above sea level is the optimal altitude to plant Castor. According to Nielsen *et al.* (2011), Castor only requires

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